BEST AVAILABLE COPY

Structural Bonding in Automotive Applications

by Peter Born, Bernd Mayer – Henkel Technologies Automotive

With automotive adhesives becoming more and more accepted in various new functions in car body structures in recent years, the development of new innovative polymer-based products alone is no longer sufficient. Modern integrated development concepts therefore address the whole process chain, from the prediction of final adhesive performance to the line implementation in the car manufacturing plants.

Combining different light substrates within one structure

On today's car production lines, adhesives are widely used for applications during all process steps from the bodyshop to final assembly. In the 1960s, the driving forces for chemical joining were corrosion protection within metal joints and an improvement in stiffness. Meanwhile, so-called crash-resistant adhesives can even meet safety-related requirements [1, 2, 3]. In addition to the development of new material concepts, efforts are increasingly being made to simultaneously develop simulation models for those adhesives and to gain knowledge of process optimisation.

Lightweight Design Concepts

Reducing the weight of cars is a major driving force behind automotive development. For car bodies, this can especially be achieved by combining different light substrates within one structure. Bonding instead of other mechanical methods such as welding becomes a preferred and imperative joining technology.

In assembly lines, the use of high modulus windscreen adhesives, thus contributing to higher torsional stiffness without increasing the car body weight, or the replacement of glass side windows by polycarbonate ones are other typical examples.

In all cases, advantages from adhesive joining such as

- homogenous stress distribution,
- possibility to combine different type of substrates
- no heat effects on substrate structures

could not be sufficiently used without proper integration into the different specific manufacturing processes.

Structural Bonding in Car Body Applications

The most important difference between the classical high-strength adhesives and those that are now being used more and more in body construction requiring dynamic performance – so-called "crash performance" – is their different behaviour under high dynamic stress. Therefore, in addition to traditional mechanical performance data such as shear or elastic modulus, test data obtained at high test speeds (even up to > 10 m/s) have to be monitored over the whole operating temperature range from – 40 °C

Figure 1: Laboratory test specimen (impact peel).

In today's car production lines, adhesives are widely used for applications during all process steps from the bodyshop to final assembly.

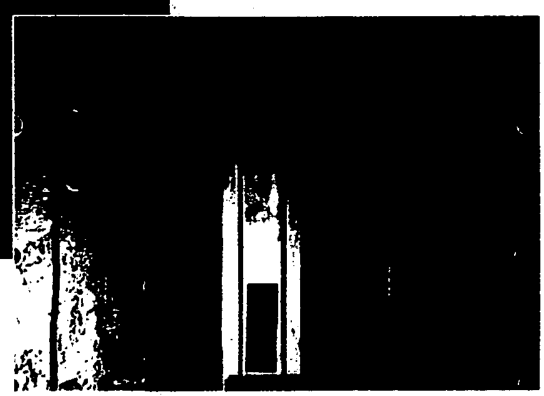

Figure 2: Drop tower test.

up to at least + 90 °C (cf. ISO 11343). By scaling up these dynamic tests from a laboratory test specimen, Figure 1, tests on structures that are similar to real automotive structures are often performed, Figure 2 and 3.

Figure 4 shows some results comparing the level of dynamic stress energy measured in drop tower tests on box beams shown in Figure 3, using bonding combined with spot welding as the joining technique. The homogenous stress distribution in the bond line leads to a significant increase in energy absorption compared to spot welding. Especially with a view to recent developments with regard to substrates, such as high strength steel, new aluminium alloys, patchwork panels, etc., and also with a view to the production process flow in car production lines, the final result does not only depend on the mechanical data obtained for the adhesives. A lot of parameters that all depend on other "partners" within the process chain can also influence the performance of the bonded joints.

For this reason, chemical product development is not only directed at steadily increasing the dynamic mechanical performance level but also at filling technical gaps between the traditional high strength adhesives and those that have good crash performance. This move will increasingly allow the use of adhesives in future in a kind of tool box approach, in which the adhesive performance level can be selected according to specific design requirements. As will be shown in a later section of this article, additional research is required with regard to adhesive performance simulation.

Adhesive in a kind of tool box approach

Figure 3: Box beam after test

Lifetime assessment of structurally bonded joints

Structural Foams

Modern lightweight structures are supported not only by adhesive bonding. Structural foams also contribute to the overall car body stiffness and crash performance. When the basic properties of adhesive technologies are compared with metals, the much lower specific weight of those organic compounds is, of course, a baseline for further concepts of weight reduction. Based on similar crosslinking chemicals that cure within existing e-coat oven temperature/ time windows when applied in a bodyshop, or by two-component curing mechanisms when applied after coating ovens, structural foams can be used for reinforcing hollow frame sections (such as the nodes between pillar and rail sections) or flat panels (panel reinforcing). The foams could then replace steel reinforcements, which are heavy compared to organic foams, or allow the use of thinner panel structures. Typical application areas are shown in Figure 5, where the major targets are reduced intrusion (for frontal, offset and side crash) and improved deformation behaviour. Furthermore, like structural adhesives used instead of spot welding, these structural foams can contribute to higher torsional or vibrational stiffness, thus improving the NVH (noise, vibration, harshness) performance of the car bodies.

Simulation of Adhesive Bonding

Lifetime assessment of structurally bonded joints is one of the major fields of basic research for car manufacturers and adhesive suppliers. Whereas bonding performance under static load is often calculated using material data such as shear and elastic modulus and Poisson numbers, lifetime prediction – especially under dynamic load and environmental conditions – is not yet fully predictable. In addition to joint research projects that are still ongoing [4], more and more distinct results – especially modelling failure behaviour – become available for structural adhesives and structural foams. Figure 6 illustrates the results of studies on structural foams, in which numerical models describing crack initiation and crack propagation under compression stress were developed. Further activities in this field of work can be expected for the near future, since a better understanding of computer simulation will increase the use of structural bonding and reinforcing in truly "designed" applications.

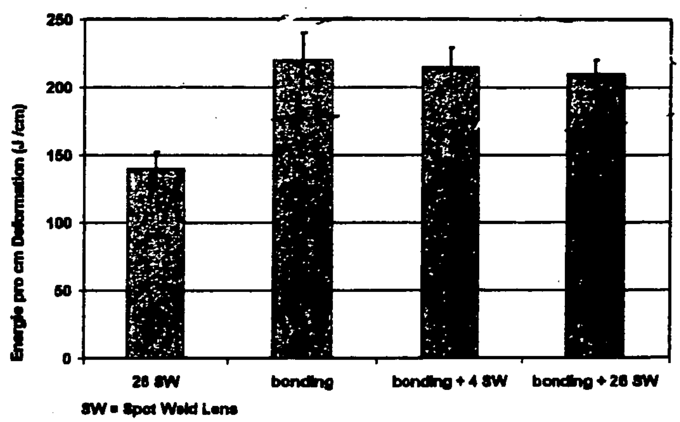

Figure 4: Level of dynamic stress energy measured in drop tower tests on box beams.

Application Technology

Especially for structural bonding applications in the bodyshop (metal bonding) or assembly line, such as module bonding and windscreen bonding, most car production lines operate with a high degree of automation. With cycle times becoming shorter, the reliability of the whole application process (from the pumping station up to the dispensing nozzles) is of increasing importance for the final quality. Besides the development of numerical simulation models, the systematic engineering of application performance is an essential part of modern integrated development concepts. In the following, examples of typical application aspects such as sag resistance and stringiness are presented.

In applications like windscreen bonding, in which the bond line geometry requires stable adhesive beads to be applied for gap bridging, so-called sag resistance is one of the most relevant application performance parameters. With high robot speeds of up to 450 mm/sec, adhesive beads with dimensions of up to 8 mm x 12 mm have to positioned without losing their wet stage shape before final assembly. Henkel has set up technology centres in Europe to support chemical product development by the additional analysis of functional (e.g. car acoustics) or line-related (e.g. pumping and application) material behaviour. By establishing own robot stations close to analytical chemical laboratories, studies could be performed in the last two years to investigate wet material properties using such methods as oscil-

lation rheology in order to predict application performance for defined line conditions [5]. Using specifically designed rheology programmes from oscillation measurements application parameters such as stringing, Figure 7, and sag resistance could be correlated to mechanical wet material properties. This represents a further step forward towards shorter line implementation times, since line trials at the car plants can be substantially reduced by simulation using these new tools.

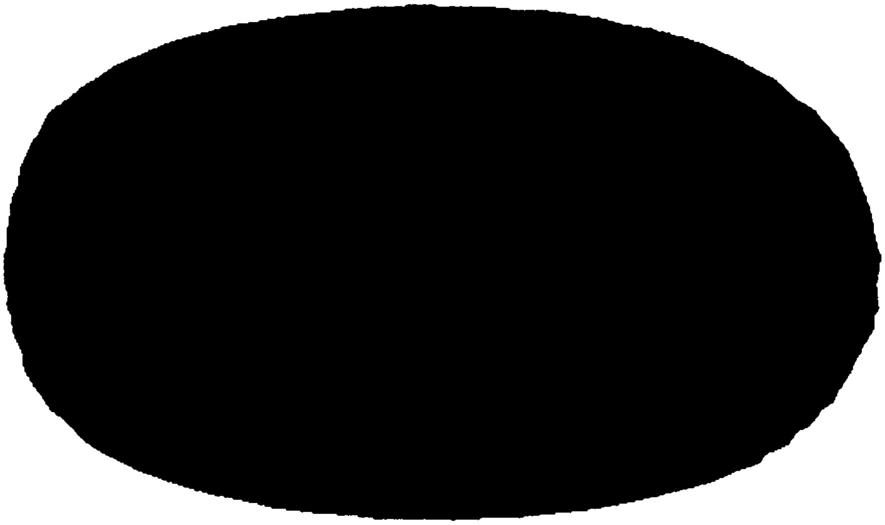

Figure 6: Results of simulation studies on structural foams.

Summary

The bonding of automotive structures in the bodyshop and assembly lines can nowadays be considered as an established joining technology. With car model life cycles becoming even shorter in future, non-chemical process development will be a future key success factor, influencing the growth potential of adhesive applications in new car models. Integrated development concepts that combine polymer product development with competences such as application and process expertise and the computer simulation of bonded joint performance will be widely used for all technologies and will further contribute to fast and low-cost line implementation, once the chemical development has been completed and the materials approved.

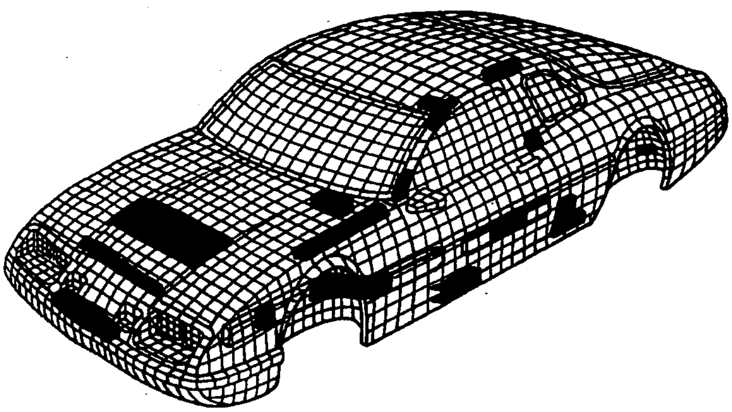

Figure 5: Application areas where structural foams are used.

[1] S. Fays: Proceedings SwissBonding 2003, 129 - 140

[2] A. Lutz, D. Symietz, Auto Technology 5/2003, 42 - 46

[3] O.-D. Hennemann, Proceedings Euroforum Oct. 2003, 1 - 47

[4] M. Schlimmer et al., 3rd Colloqium "Gemeinsame Forschung in der Klebetechnik", Düsseldorf, 2003

[5] P. Born, Proceedings SwissBonding 2003, 193 - 197

Figure 7: Stringing, a key application performance parameter for defined line condition.